CHAPTER 4

SITE SELECTION

4.1 PRIMARY REQUIREMENTS

The primary consideration in the selection of any shore radio site is the suitability, or technical adequacy, of the site for meeting the communication performance objectives. Generally, the objectives are (1) maximum signal-to-noise ratio at the receivers and (2) maximum effective power radiated in the desired direction from the transmitters. However, other factors enter into the selection of sites for communication facilities and certain compromises are usually involved before the final selection is made. This is a normal situation for engineering work, but the planner must determine that compromises in favor of economy, logistic convenience, or other factors will not preclude satisfactory circuit performance.

Radio-frequency noise and topography are the principal considerations for technical adequacy, but suitability for construction at reasonable cost, link requirements between components of the communications station, land costs, and logistic support requirements must also be considered.

The considerations leading to the selection and proper development of the site must be understood and applied to the site development plan. These considerations must be taken into account in arriving at the basic requirements for the project, and should be cited in the BESEP. The BESEP (or possibly another type of planning document) contains detailed resource requirements for a proposed communication facility and sets forth technical details bearing on site selection. Numerous factors, including those listed in this chapter, must be considered carefully in the final selection of a site. A preliminary study of topographic maps and other information concerning the area may help in eliminating certain sites from consideration. At the same time, potential sites can be identified. Then these sites can be investigated more thoroughly by on-site survey teams. Forms for use by teams investigating potential sites are contained in appendices B, C and D. Appendix B is to be used for surveying a proposed receiver site, appendix C for a transmitter site, and appendix D for a communication center site.

Numerical limitations are not specified for individual factors involved in the choice of a site since final selection is a matter of subjective judgement based on a composite of many factors, not all of which are technical. The choice of a site usually involves compromises which should not be affected by arbitrary decisions concerning any single factor.

The possibilities for future expansion are an important consideration in site selection, and comments concerning the expansion potential should be included in the site survey report whether or not requirements for expansion are given in the BESEP.

4.2 SIGNAL SURVEYS

Because of the variable behavior of the ionosphere, it is generally impractical to evaluate long-distance signal reception at a proposed site by means of signal field-strength measurements. Statistically significant data for sky-wave transmissions cannot be obtained by measurements taken over a short time. It is, however, feasible to assess the utility of a site for successful transmission or reception of ground-wave signals and to make measurements for this purpose.

4.3 RF NOISE LEVEL

The radio-frequency noise level is of primary significance for a receiver site and of less importance for a communications center or a transmitter site.

4.3.1 Receiver Site

For reliable reception of weak signals from distant stations, the receiving antennas must be located in an electromagnetically quiet area, one relatively isolated from man-made noise. Of the three major sources of RF noise, galactic, atmospheric, and man-made, the latter is of chief concern since it is the one over which some control can be exercised. The importance of locating a receiver site in an electromagnetically quiet area is illustrated in figure 2-8. A comparison of the curves of man-made noise levels for "remote unpopulous," "rural," "residential," and "industrial" areas clearly points out the difference in noise level between the "industrial" and "remote unpopulous" areas (approximately 40 dB for frequencies between 10 and 30 MHz). The galactic and atmospheric noise curves shown in the figure illustrate the inverse relationship between frequency and noise. The radio noise levels of figure 2-8 (and also of A-28) for "remote unpopulous" areas may be converted directly to the values of the CCIR Report 322, which expresses noise in terms of KT_ob, by subtracting the valves of figure 2-8 from 204.

Once established in a quiet area, a receiver site must be protected from encroachment to ensure it will remain quiet. Wherever possible, this protection should be secured by legal procedures. Future construction that may adversely affect communications should be legally prohibited within a zone, shown in figure 4-1, surrounding the site beyond the station-owned protective corridor. Registry of this encircling land area in accordance with local and state laws to restrict further development is the most desirable means of providing necessary site protection. Alternative methods of ensuring protection of the quiet zone are through zoning regulations which limit land development (again, registry in accordance with local and state laws is required), or by entering into land-use covenants with all owners of the required restricted land area. However, these two alternative methods are generally less effective because of increased real estate costs, time consumed in negotiation, and possible future litigation.

a. Receiver Site Isolation Requirements. Table 4-1 gives criteria for separation of a receiver site from other components of a communications station and from sources of interference. This data, although proven valid by experience, is usually verified by signal and noise measurements at the sites being considered.

b. Receiver Site Man-Made Noise and Unwanted Signal Survey Requirements. Field strength measurements must be made at receiver sites to evaluate the level and population of unwanted signals, to establish the ambient noise level, and to

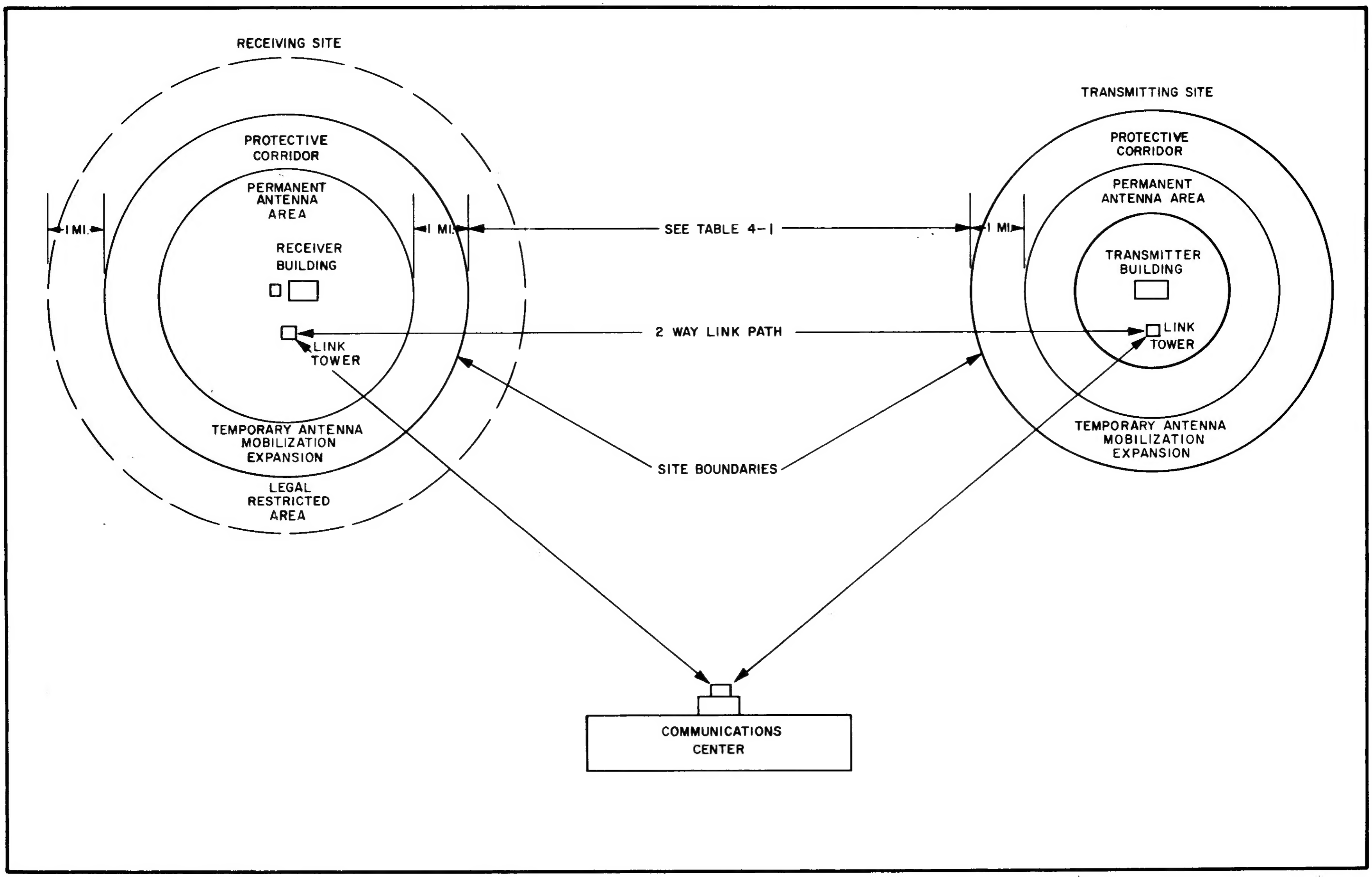


Figure 4-1. Separation Criteria for Naval Communications Station Components

Table 4-1. Receiver Station Separation Distances

SOURCES OF INTERFERENCE	MINIMUM DISTANCE
High-power transmitter stations:	
VLF	25 mi
LF/HF	15 mi
Other transmitters not under Navy control	5 mi (see note 1)
High-voltage power lines 100 kV or greater:	2 mi
Receiver station power feeders:	1000 ft from nearest antenna
Airfields and glide paths:	
For general communications	5 mi
For aeronautical receiving at air station	1500 ft
Teletype and other electromechanical systems:	
Low level operation or installed in shielded room	No minimum
High level operation installed in unshielded room	
Large installation (communications center)	2 mi from nearest antenna
Small installation (1 to 6 instruments)	200 ft from nearest antenna
Main highways:	1000 ft
Habitable areas (beyond limits of restriction) :	1 mi
Areas capable of industrialization (beyond limits of restriction - see note 2) :	
Light industry	3 mi
Heavy industry	5 mi
Radar installation:	(See note 3)
Primary power plants:	5 mi

Note 1: The following NAVELEX requirements also govern distances to non-Navy transmitter stations:
(a) Signal from non-Navy station shall not exceed 10 millivolts per meter (field intensity) at Navy site boundary.
(b) Harmonic or spurious radiation from the non-Navy station shall not exceed 5 microvolts per meter (field intensity) at the Navy site boundary.

Note 2: The restriction limit is the protective corridor; i.e., that area between the outer limits of antenna field and the site boundary.

Note 3: Calculate using "Electromagnetic Prediction Techniques for Naval Air Stations," White Electromagnetics, Inc., Rockville, Maryland, NObsr 87466.

locate sources of RF interference. An initial survey with mobile equipment is well advised. Spot checks on main highways and country roads located within ten miles of the site can identify noise sources and give an indication of the potential interference level. The utility of this type of preliminary noise survey improves in proportion with the time one spends in obtaining data at various times of the day at many locations.

Ultimately, a final survey must be conducted from near the center of each receiver site being considered seriously. This survey should extend over sufficient time (usually several days) to gather statistically significant data for the man-made noise characteristics of the site. Noise field strength measurements must be recorded to determine the ambient noise level for the site throughout the frequency spectrum of interest at various times of the day.

It is not always possible to separate individual noise sources from the composite noise level. One way to determine the level of a particular source is to make measurements at the source and determine the effect at the receiving site by calculating the attenuation as the inverse of the distance squared. Use of a loop antenna to provide directivity will aid in determining the direction of the source of interference from the station.

4.3.2 Transmitter Site

The principal concern in selecting a transmitter site is its potential for creating RF interference with other operations such as receiving stations and local commercial broadcast reception. This, and the large area needed for the antenna park forces the choice of a site remote from populated and industrial areas.

An extensive noise survey is usually not required. Siting transmitters in an area where interference will not cause adverse effects is more important than choosing a site with a low ambient noise level. The criteria given in table 4-2 apply to separation of the transmitter site from other facilities.

4.3.3 Communications Center

In general, the RF noise level ranks low among other factors that influence or dictate the location of a communications center. Operational and administrative considerations are often decisive, as long as other less-than-ideal conditions can be either tolerated or improved.

As with the transmitter site, a noise survey is not generally required, but care should be taken to separate the communications center from large generators, power transformer stations, heavy industrial equipment, high-powered HF transmitters and other obvious sources of interference. A principal objective is to prevent high-level noise or signals from interfering with DC signaling within the communications center. The established separation criteria are given in table 4-3.

Many communications centers are located on naval stations near the commands being served. However, proximity to the subscribers is only one factor to consider, not a controlling consideration. The site must be selected on the basis of overall operating efficiency consistent with economy and technical requirements. For example, a site selected for direct line of sight between the communications center and the transmitter and receiver sites will reduce the difficulty and expense

Table 4-2. Transmitter Station Separation and Clearances

FACILITY	MINIMUM DISTANCE
Overhead high-tension power lines	1000 feet from nearest antenna
Main highways	1000 feet
Other transmitter stations	3 miles
Airfields and glide paths	3 miles when the station is used for general purpose communications — 1500 feet when the station is used in conjunction with air operations
Communications center	25 miles when VLF transmitters are installed — 15 miles when LF and HF transmitters are installed
Receiver site	25 miles when VLF transmitters are installed — 15 miles when LF and HF transmitters are installed

of establishing microwave links between the sites. This advantage may outweigh other factors such as proximity to a major command.

4.3.4 Relationship Between Sites

The criteria shown in figure 4-1 for separation between components of a communications station are intended primarily to avoid radio frequency interference. Additionally, the requirement for interconnecting links is important in selecting relative locations favorable to line-of-sight microwave transmission. The maximum distance between transmitter and receiver stations is limited only by the microwave path and logistics. For the majority of applications this distance should be limited to about 30 miles. This normally will permit operation of a single-hop microwave system and will allow each component of the station to be supported logistically from a centralized location.

4.4 TOPOGRAPHY

An accurate, detailed description of the surface features of potential HF transmitting and receiving sites is necessary before a meaningful trade-off study can be undertaken to select the best site. However, a preliminary survey or map study of the general area may quickly rule out obviously unsuitable sites and may establish the marginal features of those sites to be investigated further.

Table 4-3. Communications Center Separation and Clearances

SOURCE OF INTERFERENCE	MINIMUM DISTANCE
VLF transmitters	25 miles
LF, HF transmitters	15 miles
Transmitters not under Navy Control	5 miles*
Main highways	1000 feet
Areas capable of industrialization	3 miles (light industry) 5 miles (heavy industry)
Radar installation	1500 feet
Primary HF receiver building and antenna field	1 mile
Primary power plant	1500 feet

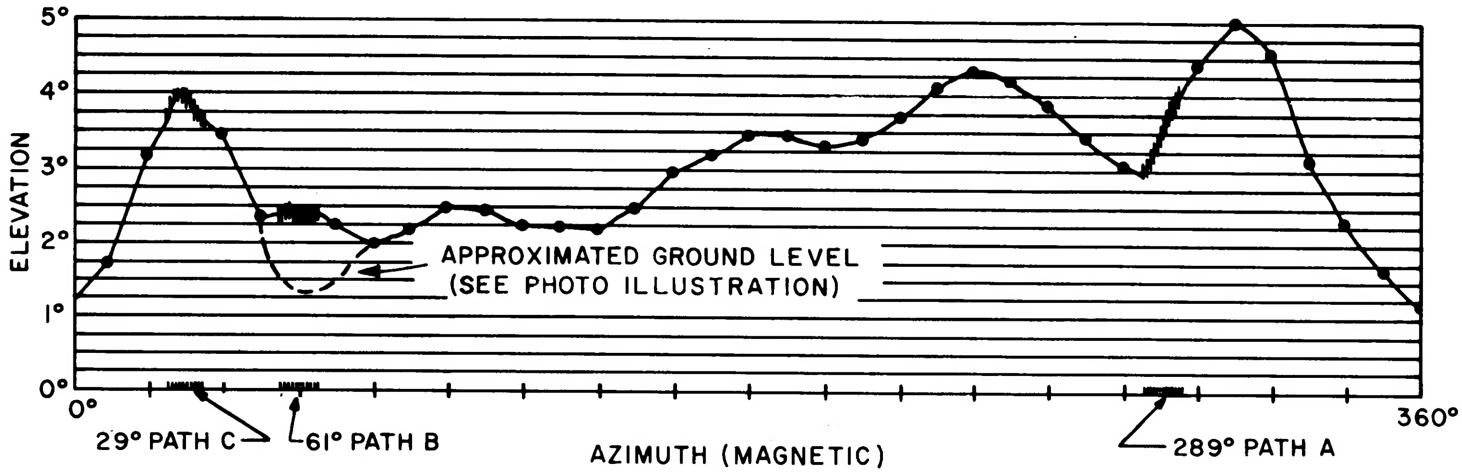
*Signal from a non-Navy station may not exceed 10 millivolts per meter (field intensity) at the location of the building.

4.4.1 Practical Objectives

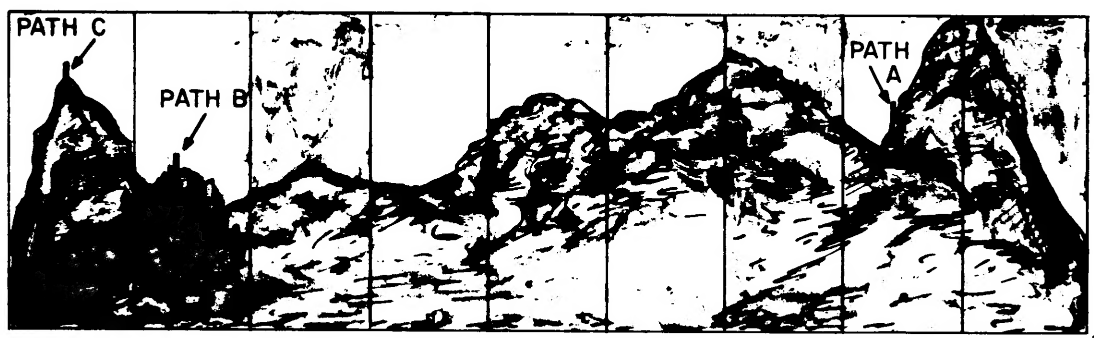
Ideally, an antenna park should be located on flat, highly conductive ground with no obstructions on the horizon. The practical objective, however, is to find a sufficiently large area of reasonably flat or rolling terrain with no obstructions extending more than 5° above the horizontal plane from any point in the antenna field. Areas of rock outcroppings should be avoided since this type of ground will have non-uniform ground constants and will increase construction costs. Again, being practical, an obstruction above the 5° radio horizon may be acceptable depending upon its location relative to the desired directions of propagation.

4.4.2 Site Profiles

The radio horizon profile of each potential site should be documented in a manner appropriate for the site being considered. In some cases, a simple statement that the land is flat with a perfectly clear horizon all around is sufficient. In other cases, such as when an installation must be made in generally undesirable terrain, a detailed azimuth-elevation profile must be made. Such a profile may be drawn by using a transit and a compass with the azimuth readings corrected for the local magnetic variation. Normally, plotting the elevation at 10 increments of azimuth will be satisfactory. In those cases where sites with obstructions must be considered, additional data should be plotted near the azimuths of the anticipated



a. PROFILE DRAWING



b. COMPOSITE PANORAMIC PHOTOGRAPH (ILLUSTRATION)

Figure 4-2. Site Profile Presentations

propagation paths. A sample plotted profile is shown in figure 4-2a with additional elevation plots centered on the azimuth of each of three anticipated paths.

Photographic techniques can be used to produce site profiles that show considerably more detail than does a plotted profile. When such detail is considered necessary, a leveling transit used with a panoramic camera is the simplest, most direct approach. However, the specialized equipment needed is normally available only by contracting for the work. Alternatively, an ordinary camera can be used to portray the horizon by making a number of exposures around the horizon and identifying the azimuths of prominent skyline features so that the photographs can be combined into a composite such as that shown in figure 4-2b.

4.5 GROUND CONSTANTS

The conductivity and dielectric constant of the earth are of concern in site selection primarily because of their effect on ground-wave propagation. Secondary considerations involve the effect of these electrical characteristics on antenna patterns and on the ability to obtain a satisfactory ground connection for power and for the electronic equipment.

4.5.1 Effect on Ground-Wave Propagation

As discussed in chapter 3, the conductivity and dielectric constant of the ground along the propagation path have a marked effect on ground-wave signal strength. The propagation charts of chapter 3 show these effects clearly.

If a site will be used for ground-wave transmissions to or reception from ships, a location close to the shoreline is obviously best. However, if a shore site cannot be obtained and inland sites must be considered, suitability can be estimated initially from the charts given in chapter 3. Figure 4-3 shows typical values of ground conductivity within the United States and table 4-4 lists typical values of dielectric constant and conductivity for various types of terrain. For practical purposes assume "Poor" ground conditions for initial computations. Although methods of measuring soil conductivity exist (two methods are presented in NAVELEX 0101, 102, chapter 12), a more practical method of investigating propagation conditions is to transmit signals from various sites and measure their respective signal strengths along the coast line or preferably aboard a ship at sea.

4.5.2 Effect on Antenna Performance

The electrical characteristics of the ground for an antenna park affect the antenna radiation patterns, but in a relatively minor way. The importance of a uniformly high soil conductivity has decreased as antenna design techniques have improved.

Ideally, vertically polarized antennas should be located in areas of high ground conductivity to provide a low-loss return path for ground currents. In actual practice, however, the importance of high ground conductivity is minimized by the fact that vertical antennas (discones, sleeves, conical monopoles, etc.,) normally are installed over a metallic ground system to ensure the low-loss return current path, and to provide impedance stability over the design bandwidth of the antenna.

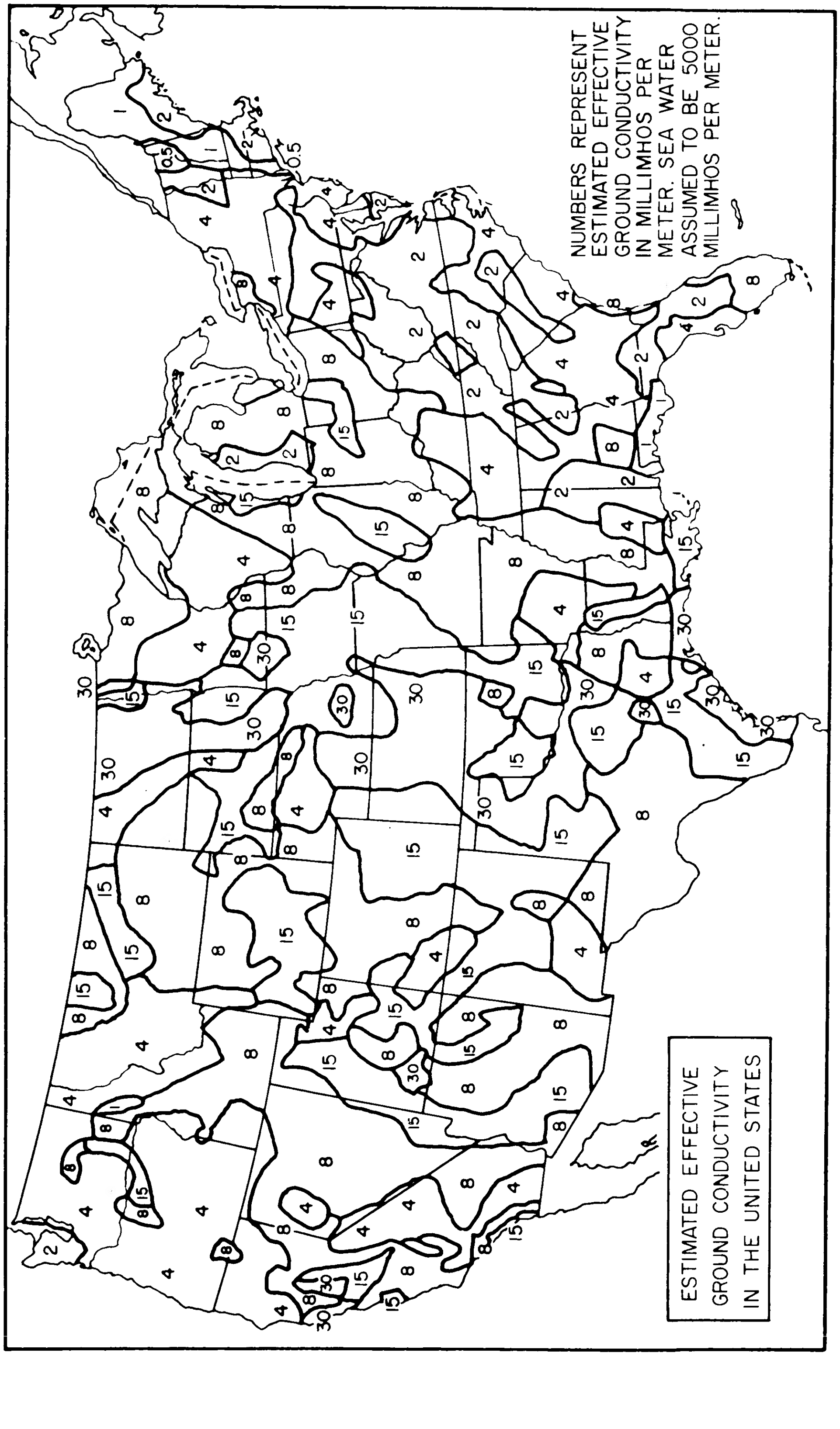


Figure 4-3. Ground Conductivity in United States

Table 4-4. Typical Ground Constants

TYPE OF TERRAIN	DIELECTRIC CONSTANT	CONDUCTIVITY, mhos/meter
Fresh Water	80	1×10^{-3}
Sea water, minimum attenuation	81	4.64
Pastoral, low hills, rich soil, typical of Dallas, Texas; Lincoln, Nebraska area	20	3×10^{-2}
Flat country, marshy, densely wooded, typical of Louisiana near Mississippi River	12	7.5×10^{-3}
Pastoral, medium hills and forestation, typical of Maryland, Pennsylvania, New York, exclusive of mountainous territory and seacoasts	13	6×10^{-3}
Rocky soil, steep hills, typical of New England	14	2×10^{-3}
Sandy, dry, flat, typical of coastal country	10	2×10^{-3}
City, industrial areas, average attenuation	5	1×10^{-3}
City, industrial areas, maximum attenuation	3	1×10^{-4}

*To convert mhos per meter to emu, multiply by 10^{-11}.

In cases of horizontally polarized antennas, e.g., rhombics, an ideal location is one where a body of water extends several miles in front of the antenna. However, these antennas perform efficiently if they are located over reasonably flat ground, and have an unobstructed path in the desired propagation direction. Generally, horizontal antennas do not require high ground conductivity for effective sky-wave propagation. The electrical characteristics of the earth have little effect so long as the antenna is erected at least one-quarter wavelength above the earth's surface.

Since the soil conductivity at a potential antenna park is of relatively minor importance compared to other factors, extensive measurements of conductivity throughout the area are not required. Reasonably flat terrain, and economic and logistic support requirements for the site are overriding considerations in most cases.

4.5.3 Effect on Establishing Station Ground

Soil conductivity measurements are required to determine the feasibility and

difficulty of establishing a ground connection adequate for personnel and equipment protection. In general, one connection to ground is made for this purpose, and all power and equipment grounds are connected to a ground bus leading to this connection. This subject is discussed in NAVELEX 0101, 102, chapter 12, where a standard method of measuring the ground connection is given.

4.6 HF RADIO FREQUENCY HAZARDS

Radio frequency (RF) radiation is a potential hazard to personnel, certain types of ordnance material, and fuel supplies. As such, it is a factor to be considered in selecting HF transmitter sites.

In recognition of RF hazards, various criteria have been established by responsible commands and agencies. A recent confidential directive, NAVORD 3565/NAVAIR 16-1-529 — "Technical Manual, Radio Frequency Hazards to Ordnance, Personnel, and Fuel" (U), has been issued on the subject. Although the principal criteria set forth in this directive concern the shipboard RF environment, some criteria for shore stations are also prescribed.

Compliance with the separation and clearance criteria for location of HF transmitter sites given in table 4-2 will eliminate much of the potential hazard normally associated with electromagnetic radiation.

4.6.1 Hazards to Personnel

RF radiation can be hazardous to personnel in two different ways — either through absorption of radiated energy by various parts of the body or through physical contact with induced voltages resulting in shock and/or RF burns.

a. Absorbed Radiation. Presently known detrimental effects of overexposure to RF radiation are associated with the average power of the absorbed radiation, are thermal in nature, and are observed as an increase in overall body temperature, or as a temperature rise in certain sensitive organs of the body. It has been determined that normally for any significant effect to occur, a person's height would have to correspond to at least one-tenth of a wavelength at the radiation frequency.

The Bureau of Medicine and Surgery has established safe limits based on the power density of the radiation beam and the exposure time of the human body in the radiation field as follows:

(1) Continuous Exposure. Average power density not to exceed 10 milliwatts per square centimeter.

(2) Intermittent Exposure. Incident energy level not to exceed 300 millijoules per square centimeter per 30-second interval. (Power density, in mw/cm^2, divided into 300 gives the portion of a 30-second interval that is safe for intermittent exposure.)

(3) Hazardous Areas. All areas in which the RF levels exceed prescribed safe limits shall be considered hazardous. As a general rule, small aperture antennas such as dipoles operated at high power levels present the greatest potential hazard because their power density is concentrated in a small area near the antenna.

The area in the vicinity of HF transmitting antennas should be restricted to prevent inadvertent entry into hazardous areas. In all cases, restriction must be enforced to prevent personnel from being exposed to either continuous or intermittent power levels in excess of the prescribed safe limits.

b. Shock and RF Burn Hazards. In addition to the direct radiation hazards to personnel there also exist hazards from shock and RF burns. The hazard attendant to physical contact with a radiating antenna is well recognized, but shock hazards can also arise from voltages induced upon metal objects by electromagnetic radiation. These induced voltages can be of sufficient magnitude to create a shock hazard and/or cause RF burns to personnel. Similarly, the induced voltages may produce open sparks or arcs when contact between conductive objects is made or broken. Hazardous conditions caused by RF induced voltages can be reduced considerably by proper grounding and bonding of buildings and equipments. Methods for grounding and bonding of buildings and equipments are discussed in NAVELEX 0101, 102.

4.6.2 Hazards of Electromagnetic Radiation to Ordnance (HERO)

Electromagnetic radiation can, under certain conditions, detonate electroexplosive devices (EEDs) contained in ordnance materials. NAVORD 3565/NAVAIR 16-1-529 lists three classifications of ordnance materials based on the susceptibility of these materials to radiation hazard: (1) HERO SAFE, (2) HERO SUSCEPTIBLE, and (3) HERO UNSAFE.

The HERO UNSAFE ordnance materials are the most susceptible to RF radiation and constitute the "worst case" situation for shore communications transmitters. Any ordnance item is defined as being HERO UNSAFE when any of the following conditions exist:

a. When its internal wiring is physically exposed.

b. When additional electrical connections are required for the item being tested.

c. When handling or loading EEDs having exposed wire leads.

d. When assembling or disassembling the item.

e. When the item is in a disassembled condition.

Ordnance items that are in one of the above conditions may be exempted from being classified as HERO UNSAFE as the result of previous HERO tests or analyses which are recorded for specific equipments in the NAVORD/NAVAIR directive.

The above directive prescribes that measurements of field intensity will be used to ascertain the magnitude of an electromagnetic field, and further prescribes that the field intensity of electromagnetic fields at communications frequencies (200 kHz to 1000 MHz) will be referred to in terms of vertical electric field strength in units of volts per meter. A chart in the directive indicates that for HERO UNSAFE ordnance the maximum safe field intensity is 0.2 V/m throughout the 2 to 32 MHz frequency range.

The established criteria of a maximum vertical field strength of 0.2 V/m for HERO UNSAFE ordnance could become a stringent restriction for radiation from communication transmitters of reasonably high power. A table in the NAVORD/NAVAIR directive shows a minimum distance of 8700 feet for HERO UNSAFE ordnance exposed to a 5-kW transmitter operating in the CW mode, and 17,400 feet for the same transmitter operating amplitude modulated.

The foregoing distance and field intensity restrictions are based on unprotected HERO UNSAFE ordnance materials which present the worst conditions that may be encountered. However, a number of ordnance systems are HERO SAFE (not susceptible to radiation) under all conditions, and a large majority of other ordnance systems are classified as HERO SUSCEPTIBLE under most conditions. The maximum safe field intensity prescribed for HERO SUSCEPTIBLE ordnance is 2.0 V/m throughout the 2 to 32 MHz frequency range.

Since the allowable maximum safe field intensity varies widely for the three classifications of ordnance systems it is quite important to ascertain from competent authorities whether ordnance systems will be handled or stored in the vicinity of a proposed transmitter site. If items of ordnance are to be handled or stored, the classification of the ordnance most sensitive to RF radiation will determine the maximum field strength that can be tolerated.

4.6.3 Fuel Hazards

Although the problem of fueling in an RF environment has been the subject of extensive research and study, precise criteria have not been developed.

a. General Guidance. General guidance, based on NAVSO P-2455 — "Safety Precautions for Shore Activities," is as follows:

(1) Transmitters with 250 watts radiated output or less should not be installed within 50 feet of fuel handling or fueling areas, and

(2) Transmitters with over 250 watts radiated output should not be installed within 200 feet of fuel handling or fueling areas.

Although the second portion of the above guidance implies that no problem would exist for distances greater than 200 feet, regardless of the radiated power, this is not the case. For transmitters with output power in excess of 250 watts, separation from a fuel handling or fueling area should be such that the power density in the fueling area is no greater than would exist at a distance of 50 feet from 250 watts radiated output. Figure 4-4 shows the distance in feet from a conical monopole antenna required for various transmitter power outputs to provide the equivalent power density that would exist at a distance of 50 feet from 250 watts radiated power output. Because of the many factors involved, the above approach is considered only as general guidance and therefore should serve as an approximate method of determining whether a fuel hazard may exist. Upon completion of an installation, tests should be conducted to determine if arcing occurs in fuel handling or fueling areas.

b. Conditions for Gasoline Ignition. In order for high octane gasoline to be ignited by RF induced arcs, all of the following conditions must exist simultaneously:

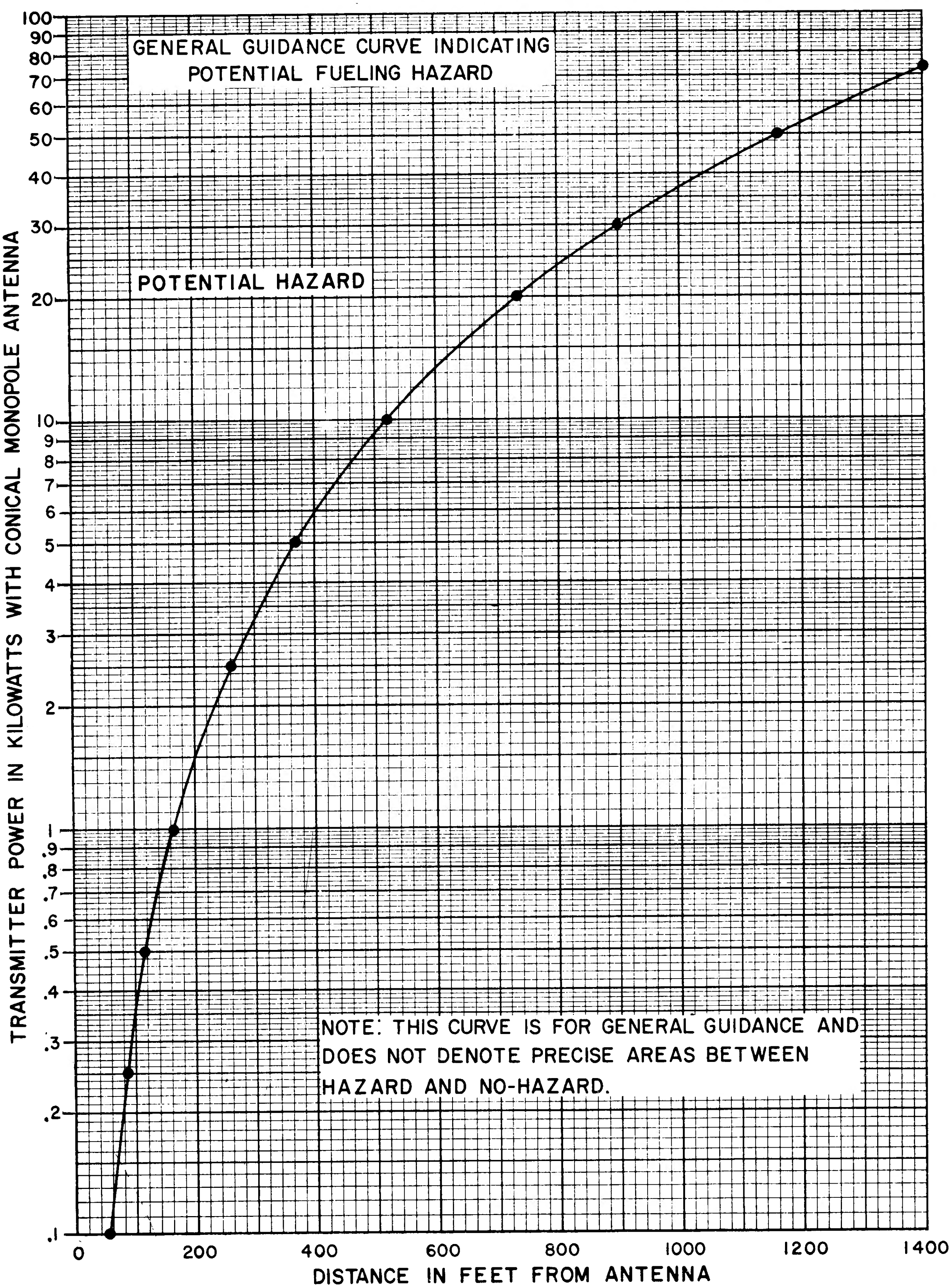


Figure 4-4. General Guidance Curve Indicating
Potential Fueling Hazard

(1) A flammable fuel-air mixture must be present within range of the induced arcing. The limits of flammability of most gasolines are between 1.25 and 7.6 percent by volume of gasoline vapor in air. With air movement, the vapor is diluted and swept away reducing the zone of possible ignition.

(2) The spark must contain a sufficient amount of energy to cause ignition. Tests aboard ship have revealed that a volt-ampere (VA) product of 50 or more was required to ignite gasoline in an explosive vapor test device.

(3) The gap across which the spark occurs must be a certain minimum distance. A minimum spark gap of about 0.02 inch is required for ignition of a proper fuel-air mixture. This requires metal-to-metal contact and subsequent withdrawal to produce a drawn arc of sufficient length to ignite such a mixture. Drawn sparks may be observed in an RF environment where the VA product is less than the 50 required for ignition, but such an arc is not of sufficient length to cause ignition.

NOTE

Although the probability of these three conditions occurring simultaneously is relatively low, extreme caution must be exercised since the possibility does exist and the consequences of an explosion are usually quite severe.